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Mars Global Surveyor (MGS) High Temperature Survival Solar Array Design

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Introduction

The MGS mission is one of the first major planetary missions conducted under the new NASA "Faster, Better, Cheaper" guidelines. Ironically, mission environmental requirements make the MGS solar array one of the most challenging designs built for NASA. In particular, the solar array will be used to **aerobrake** the **spacecraft** in the upper regions of the Martian atmosphere. This will be done in order to lower and circularize the initially high elliptical insertion orbit, as a method to reduce spacecraft mass (propulsion). The array **size** is constrained by mass and area. Consequently, even though a mission to Mars is normally typified by cold **temperatures**, **aerobraking** imposed a high temperature **requirement** of nearly 180 C. Furthermore, since the **aerobraking** occurs at the mission beginning, it is subsequently necessary to survive up to 20,000 lower **temperature** thermal cycles.

Approach

The MGS array has been designed to survive not only the initial high **temperatures** but also all expected mission thermal cycles. A combination of welding, high temperature solder, and mechanical attachments are utilized. The selection and evaluation of these processes were driven by the limited development time (weeks) and the limited **funding**. Due to the constraints, only previously qualified processes and materials were **useable**, although in some cases these had not been used on solar arrays. **Existing** processes were modified, where possible, to meet the **tight** program schedule.

Technical Highlights

At the contract start the **aerobraking** environment was not defined. As a result, the MGS array assembly process baselined welding for cell interconnections and for cell to end tab terminations. The standard solder process was to be utilized for any cell replacements, termination tab to wire connections, wire to terminal board connections, diode wiring (bypass and blocking), and terminal board to wiring harness connectors. Calculations performed by Lockheed-Martin soon indicated

that aerobraking temperatures, and in particular, aerobrake qualification test temperatures would exceed the safe operating temperatures of the standard solder material. A team, consisting of members from JPL, Lockheed-Martin and Spectrolab, was assembled to develop an alternative solder method that would satisfy the MGS requirements. Due to the limited time and funding available, it was clear that a very limited development effort could be carried out. Clearly, there was insufficient time to flight qualify any process so that heritage or slight modification of existing processes was all that could be reasonably expected. Following a review of numerous solder candidates, four high temperature solders were selected based on melting points and suitability for solar cell assembly. Three were tin/silver solder with the fourth candidate a tin lead material with 20/0 silver. These materials had minimum melt temperatures of 221 C. Samples of each array solder joint were made using each of the solders. Tip temperatures were varied, and case of flow and solder fillet condition were noted. It was noted that the most difficult joint to produce was the terminal to terminal board assembly. It was difficult to flow the solder since the board provided an efficient heat sink. The flow was improved by either switching to larger solder tips or preheating the terminal board. All solder candidates produced adequate joints which met the criteria of N1115300.4. This was important since it meant that the existing inspection criteria could be retained. The best visual joints were achieved with 95 Sn/5 Ag and the material was easiest to flow. The absence of lead was felt to provide advantages in long life fatigue resistance.

Based on these results, a development coupon was assembled in which all possible solder joints were included in a flight representative configuration. In addition, some additional materials were included where manufacturers data indicated that the materials should not survive 200 C. These included GFN copper clad fiberglass terminal board, 56C Catalyst 9 silver-loaded electrically conductive epoxy, 56C Catalyst 11, and P224 acrylic adhesive Kapton tape. The coupon consisted of two strings of seven cells in series. These included welded and repair process solder bonds. A terminal board assembly was fabricated and bypass diodes were attached to each string. 95/5 solder was used for all bonds. The coupon material was representative of the MGS substrate. The coupon was then subjected to thermal shock and thermal cycling tests in a GN_2 atmosphere. The thermal shock consisted of 8 cycles, -10 C to 200 C, and the thermal cycle consisted of 300 cycles, -145 C to 148 C. A comprehensive electrical and visual inspection was performed before and after testing. Electrical degradation was within the normal experimental error indicating that the assembly processes could survive the high temperatures. Some visual anomalies were noted. Subsequent examination revealed that one solder joint had been improperly wet initially and two others had evidence of handling damage. Of greater concern was the appearance of cracks in some of the solder fillets. A potential cause of the cracks was possible contamination from lead during iron tip tinning. Lead contamination can lead to lower melting temperature and reduced joint mechanical strength. It was felt that the use of a dedicated high temperature solder assembly area with new tooling would prevent contamination during flight assembly.

At this time, additional review of the solder properties indicated that although the solder was kept below the melting point, its mechanical strength, even for non contaminated bonds, was low at temperatures above approximately 130 C. Due to this, a decision was made to reduce any mechanical stresses at the assembly joints. In particular, welded loops were formed on the end tabs to mechanically hold the soldered wires (see figure 1). Similarly all diode attachments included hooking the lead wires together prior to soldering and sleeving with shrink tubing. In this

manner mechanical loads at the bond would be removed from the solder itself during the high temperature aerobraking. For subsequent mission thermal cycles the maximum solder temperatures would remain below 60 C and high solder strength would be available. The mechanical support would provide for an additional safety factor during the worst conditions. The MGS solar arrays are presently completing flight acceptance tests and will be delivered to Lockheed-Martin for spacecraft integration]. The launch date will be in December, 1996.

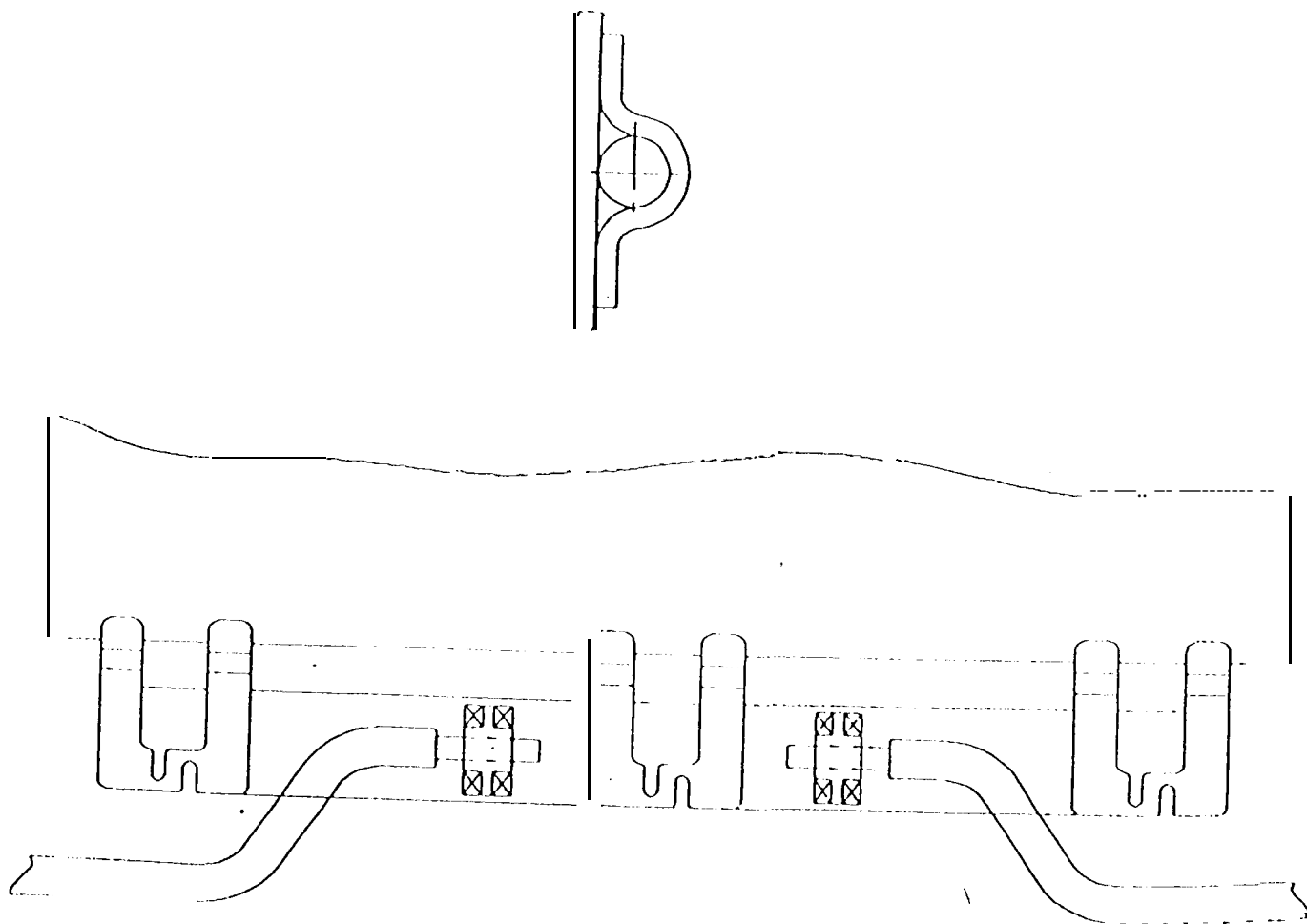


Figure 1. Welded Clamp Arrangement for Leads (Two Views)

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